Third United Nations International Conference on the Peaceful Uses of Atomic Energy

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Abstract

FUTURE ENERGY NEEDS AND THE ROLE OF NUCLEAR POWER

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The six years since the last Geneva Conference have been dynamic ones for the energy industries. Consumption of energy has grown substantially with increasing percentages being used in the form of electricity. Some of the historic production and price trends in the fossil fuel industries have been reversed or greatly altered, and nuclear power has become a significant competitive factor in the electric utility market.

Capital costs for both nuclear and conventional plants have decreased dramatically due both to technological advances and rapid increases in the size of generating units. The cost of coal, the major fuel for electric utilities, has been decreasing and new concepts in coal transportation and power transmission will further reduce the cost of power from conventional plants. Fuel cycle costs for nuclear plants have declined both as a result of technical developments and of two reductions in the Atomic Energy Commission's schedule of charges for enriched uranium. Competition between coal and nuclear power is intense in high fuel cost areas.

Energy requirements and resources, as well as the role of nuclear power, have been studied intensively in the last few years. As a result, the energy situation and future prospects are probably better understood than ever before although substantial areas of uncertainty remain. In the last three years, five major energy studies have been made by or at the request of the Federal Government, including the Atomic Energy Commission's Report to the President on "Civilian Nuclear Power." Many other important studies have been made both within and outside the Government.

The concensus of the forecasts is that total energy consumption in the year 2000 will be triple 1960 consumption. There is general agreement that

coal resources will be adequate for at least well into the next century, but divergent opinions as to the ability of technology to provide these coal resources at or below present costs. U. S. resources of crude oil and natural gas will almost certainly become scarce long before coal, although the domestic supply picture will be substantially improved by imports, shale oil, conversion of coal, or perhaps production of other synthetic fuels with the aid of nuclear power.

Even where there is good agreement as to total energy requirements there is serious disagreement as to the level of electricity demand. Responsible forecasts differ by as much as a factor of two in electricity requirements for the year 2000. Opinions also differ widely as to the rate at which nuclear power will penetrate the electricity market in the next few decades; however, the forecasts agree that by the year 2000 nuclear power will dominate the new plant market and will furnish one-half of the power generated.

In 1962 the Atomic Energy Commission made predictions of the amount of nuclear capacity to be installed through the year 2000. Developments since 1962 indicate that the growth of nuclear power will probably be faster than predicted then. Realization of predicted amounts of nuclear power are dependent upon further advances in water reactor technology and the development of advanced convertor and breeder technology. The direct economic benefits of the installation of nuclear power will be many billions of dollars by the year 2000. Substantial additional benefits will result from the stimulation of competitive fuels to reduce costs, the reduction of atmospheric pollution, the extension of resources, and the promotion of international trade.

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INTERNATIONAL COOPERATION ON NUCLEAR POWER

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The discovery that nuclear energy might be released by a neutron chain reaction in uranium was the culmination of cooperative scientific research in many nations. Ironically that discovery came just as the black cloud of war descended on the world cutting off the normal flow of information in the world community of science.

International exchange of information on nuclear energy came slowly after the war because of the appalling destructive power of nuclear weapons and because of the atmosphere of unrest and mutual suspicion. In 1945 the United States began to release the maximum of information consonant with military security and, in the Baruch plan, advanced a scheme intended to control nuclear weapons and promote the peaceful uses of nuclear energy.

The Baruch plan was not accepted but gradually information has been disseminated through bilateral arrangements including exchange of visitors, through normal channels of publication and through international conferences. The most comprehensive of these conferences were those held in Geneva in 1955 and in 1958. The published proceedings of those conferences are a notable monument to international cooperation.

The basic principles of a nuclear power reactor are very simple. This may account for early optimism about the immediate prospects for cheap nuclear power. In reality the development of nuclear power reactors that would be reliable and economically competitive with other sources of energy has proven difficult. Consequently the exchange of scientific, technological and economic information has been essential.

There are many bilateral or multilateral agreements looking toward the construction of nuclear power plants. These cooperative schemes range from the extreme of the customer country getting only information to the other extreme of a complete "turn key" package of power reactor, auxiliary equipment, arrangements for reprocessing spent fuel and guaranteed supply of new fuel.

Examples of cooperative arrangements include the Dragon project for the development of a high temperature gas cooled reactor. The Dragon project is unique in the large number of countries cooperating. Another example is the bilateral understanding between Canada and the United States whereby Canada leads the way in the development of heavy water reactors with the full cooperation of the United States.

More immediately aimed at the construction of nuclear power plants, the Euratom group was formed in 1957 and agreement for cooperation with the United States signed a year later. The change in the Euratom program since its initial announcement illustrates the shift from the exaggerated optimism of the middle fifties to the more realistic views of the present time.

Japan is constructing a series of reactors of different size and type under a variety of arrangements with a number of countries.

The United States has arrangements with more than twenty countries covering more than sixty reactors or critical assemblies which have been furnished wholly or in part by the United States and which are subject to safeguards against diversion to military use. Since most of these are small, safeguarding is not very important in practice, but it is extremely important in principle.

In connection with such arrangements as have been mentioned, there are many questions concerning health and safety, liability for accidents, waste management and so on. Of particular importance is assurance against diversion to military use. Many of these questions concern the whole community of nations, not just the country where the reactor is located.

For this reason cooperative international control is essential to the safe proliferation of nuclear power plants. Such control can and should be exercised by vigorous support of the International Atomic Energy Agency.

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THE USES AND POTENTIALITIES OF RESEARCH REACTORS

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The use of nuclear reactors as research tools is now more than two decades old. The list of experimental techniques possible with nuclear reactors is very long. The applications of these techniques are numerous, and additions are made at a steady rate in nearly all branches of science and technology.

Most of the research with reactors has been done with machines offering maximum thermal neutron flux levels between 10^{12} and 10^{14} neutrons/cm^2-second. The effective flux level for many kinds of experiments has been well below the maximum values possible. In addition, some research reactors have been designed with too little, if any, attention given to the best energy spectrum of the neutrons to be used, and to background levels. The limitations on flux levels and the lack of purity of the radiation have hindered experiments.

A new generation of research reactors seeks to reduce these problems by providing design features that are more nearly optimum for the experiments that are planned. The neutron flux is shaped in space, time, and energy, to improve the useful fraction of neutrons, and to reduce the undesirable components of the radiation.

In this paper we discuss the nuclear research reactors that have been of most interest in the United States. A historical review indicates how the trends in engineering and the nature of the research that was planned led to the types of reactors commonly used.

A review of the state of applications of research reactors is given. The capabilities of different kinds of research reactors, both present and future, for the different areas of research is discussed, including consideration of the flux intensities and characteristics that a research reactor

should have for competitive research. An analysis is made of the degree to which the advanced reactors now being built approach the features that the ideal research reactor should have.

We also discuss use of research reactors at nuclear centers in developing countries, with attention given to both the features of the reactors and the types of programs that would be fruitful. Recommendations are given on how to use the reactors in these centers to produce research competitive with that done in larger and more advanced nuclear centers.

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CONTROLLED FUSION RESEARCH IN THE U. S. A.

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The major experiments now under way in the United States to study the confinement and heating of plasma are described as well as plans for the future.

In the magnetic mirror program hot plasmas are either produced
(1) by plasma injection followed by magnetic compression (2X)
(2) by trapping ions produced from a beam of neutral atoms (ALICE)
(3) by trapping atomic ions by Lorentz dissociation of H_2^+ (DCX-1) or
(4) by dissociation of H_2^+ in a lithium arc (DCX-2). Results are reported on stabilization by control of the scale and spatial distribution of plasma temperature and density (finite orbit stabilization) and by using complex fields having a closed region of "Minimum B" similar to that of Ioffe.

Other magnetic configurations which utilize "Minimum B" magnetic fields are discussed, such as the caulked cusp and the helixion.

Recent results in the fast magnetic compression experiment (Scylla IV) are presented and a possible attack on the next stage is described.

The Astron facility consisting of a high current electron accelerator (160 Amperes at 4.1 MeV) and a trapping chamber with an axial magnetic field, has been completed. Results of experiments aimed at trapping the electrons in rotating and oscillating orbits to form a cylindrical layer are discussed.

Recent results on a torodial device with pulsed sheared magnetic fields (Levitron) using ion cyclotron heating to discriminate between instability modes are described as well as theoretical results on an $\int dl/B$ stable torodial configuration with periodic multipole structure.

The research program of the Model C stellarator using ohmic heating and various types of ion heating is discussed. Observations indicate that a pure 50 eV plasma can be produced by this technique and that a close approach to mechanical and thermal equilibrium can be achieved. The use of the divertor is discussed as well as the results on measured power radiated, energies required for ionization and heating, and power balance studies.

Hot electron plasma experiments are described in which a steady state has been maintained with the ratio of plasma pressure to magnetic field pressure, β equal to 0.3.

Also described is: supporting research on the performance of high velocity hydromagnetic guns and the behavior of the vacuum deuterium arc.

Programs in controlled fusion under way in industrial laboratories, including General Dynamics and General Electric, are discussed as well as the latest results obtained on fast magnetic compression in the Naval Research Laboratory. A brief survey of the plasma research at Massachusetts Institute of Technology, Stanford University, New York University, and the University of California at San Diego is presented.

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ADVANCES IN RADIOISOTOPE PRODUCTION AND UTILIZATION IN SCIENCE AND INDUSTRY

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Now, only three decades after the discovery that radioactivity could be artificially induced, man-made radioisotopes have been established as powerful and versatile tools for an almost countless number of uses in nearly all fields of research and application. Man-made radioactivity is truly one of those discoveries of major benefit to mankind.

Advances in the discovery and production of specific radionuclides have been phenomenal. Although around 130 radioactive species have received significant usage and are routinely produced, the potential number of useful radioisotopes is much greater. Means of production cover a variety of accelerators with great flexibility in type and energy of particles and radiation generated, encompassing the use of photons, neutrons, protons, deuterons, tritons, helium-3 and alpha particles and heavier nuclei. However, the bulk production of radioactivity is now by means of nuclear reactors. Through neutron bombardment in high-flux high-power reactors, production of most useful isotopes can be expanded to meet any conceivable need, up to hundreds of megacuries of certain isotopes such as cobalt-60. Also, vast quantities of fission products are unavoidably obtained as by-products of power and/or plutonium production. Individual radioisotopes from this source are being separated and purified in megacurie quantities. Costs of production have been greatly reduced and could

become even lower with larger demand.

Advances in radiation detectors, associated electronics technology and the automatic recording and analysis of data also have been astonishing. Use of solid scintillation counters has become routine, and crystals are available in various shapes and sizes up to 16 inches in diameter. Liquid scintillation counting has become extensively employed for efficient internal particle counting of a broad variety of sample forms. Use of liquid, plastic, and crystal detectors, with associated circuitry involving multi-channel pulse-height analysis, coincidence and/or anti-coincidence techniques, has been extended to extremely low-level counting of samples, even to the size of human beings. Recently, a variety of semi-conductor detectors have been developed that provide increased energy resolution for counting alpha particles, conversion electrons and low energy X and gamma rays. Semi-conductor detectors incorporating heavier elements are under development to permit efficient high-resolution counting of higher-energy gamma rays.

Parallel improvements and expansion in utilization of radioisotopes have taken place rapidly in all fields of application. In the basic physical sciences, the major applications are for analytical techniques, determination of molecular structure, measurement of reaction kinetics and determination of physical properties and behavior of matter. In the applied sciences, new uses are being developed in engineering and such fields as oceanography, meteorology, hydrology, other geosciences and space technology. Estimates will be presented on the increasing scope and benefits of use throughout the world in science and industry. Undeveloped potentials will be highlighted.

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ADVANCES IN NEUTRON-ACTIVATION ANALYSIS

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Great strides have been made in neutron-activation analysis since 1958. Many of the major advances in technique and applications are described in this paper.

Major improvements have been made in all three types of neutron sources used for neutron-activation-analysis work: isotopic, accelerator, and nuclear reactor sources. The older isotopic sources have now been augmented by americium-beryllium sources, and the availability of californium spontaneous fission sources is expected in the near future. These are, of course, low-flux neutron sources. Many improvements have been made in the low-cost deuteron accelerators which produce 14-MeV neutrons by means of the H-3(d,n)He-4 reaction, and such accelerators are now widely used in science and industry for medium-flux (10^7 - 10^9 n/cm^2 .sec) thermal-and fast-neutron-activation analysis. Some of these recent improvements include the use of vac-ion pumps, target refrigeration, high tritium-content targets, large rotating targets, target replenishment by means of H-3 bombardment, and magnetic deflection of D_2^+ ions. Major developments in research reactors used for neutron-activation analysis include the extensive utilization of reactors with a large-capacity, uniform-flux rotating sample rack, and of reactor pulses.

New developments in neutron-activation techniques include (1) systematic use of the high fluxes of fission-spectrum fast neutrons present in the reactor, (2) the employment of high-intensity (10^{16} - 10^{17} n/cm^2 .sec) reactor pulses for enhancement of detection sensitivities for very short-lived induced activities, (3) the utilization of delayed neutrons in the activation detection of fissionable species, and (4) the development of very rapid post-irradiation

radiochemical separation techniques, now successfully employed with induced activities having half lives as short as a few minutes.

Along with the recent advances in techniques and capabilities, and the wider appreciation of the power of the method, the application of neutron-activation analysis has greatly increased and has spread to many fields of science, industry, and medicine. The method, employing small deuteron accelerators, is now in wide use especially in the petroleum and chemical industries, for routine medium-sensitivity elemental analysis. The method has especially found a high degree of application in the field of rapid oxygen determinations, via the O-16(n,p)N-16 reaction, at levels down to about 5 parts/million of oxygen. Some of the many improvements recently made in this technique include (1) use of a dual pneumatic transfer system (for sample and standard), (2) several excellent flux-monitoring systems, (3) rotation of sample during irradiation, (4) corrections for neutron scattering and gamma-ray scattering in the sample, and (5) development of very low oxygen-content sample containers. The chemical industry has also pioneered interesting applications of pesticide-residue determinations, determination of catalyst residues in polymers, and in the activation-analysis detection of stable isotopes, such as N-15 and O-18, used in tracer studies. The coal industry has carried out interesting activation-analysis studies of the continuous determination of ash constituents in coal.

In geochemistry, important studies are being carried on in the determination of rare-earth element abundances in meteorites, in calcium isotope ratios, and in Rb-Sr age dating. With its tremendous sensitivity, the method, employing the high neutron fluxes available in nuclear reactors, is naturally finding more and more use in ultra-pure materials such as the alkali metals, Be, C, Al, Si, Ti, Fe, Ge, Zr, Nb, and Pb. A very interesting new field of application is that of scientific crime detection, in which several important advances have already been made. In the field of space exploration, a completely automatic, miniaturized neutron-activation analysis system has been developed for analysis of the surface of the moon.

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CURRENT STATUS AND FUTURE PROSPECTS FOR COMMERCIAL RADIATION PROCESSING

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Over the last decade, considerable attention has been given by researchers throughout the world to the possibility of utilizing massive amounts of ionizing radiation for industrial processing. After years of research by a countless number of organizations commercial radiation processes are beginning to appear.

This paper discusses the processes in use today in the United States in some detail. Future commercialization is also considered, including those processes that probably will become successful within the next few years. The former category includes the production of ethyl bromide, polyethylene film, crosslinked polyethylene wire and related products, semi-conductors, medical supply sterilization and sprout inhibition of potatoes. When possible, data are presented on volume production and present and future market implications.

Future processes discussed are the radiation curing of coatings, textile materials, wood plastic combinations, sterilization of meat products, pasteurization of fishery and fruit products, the use of radiation for food processing, semi-conductor devices, and other specialized radiation processes. Consideration is given to various types of irradiators - i.e., for package, bulk, liquid and solids - including discussion of design parameters and their importance.

Radiation sources as they relate to these design parameters are also considered. The potential use of cobalt-60, cesium-137 and strontium-90, and their production, encapsulated form, and present and ultimate costs are discussed in some detail.

The present and ultimate economics of radiation processing are presented, taking into account all of the previously discussed topics, present plans, and research for the future, including the use of accelerators as radiation sources.

The process radiation industry, although at present in its infancy, is beginning to take shape. It is important that these major factors affecting the industry are well understood so that the vast potential of this field will be realized.